

A FULLY NONLINEAR SHEAR FLEXIBLE SHELL MODEL AND A TRIANGULAR FINITE ELEMENT FOR THE ANALYSIS OF THIN-WALLED SHELL STRUCTURES

E. M. B. Campello^a, P. Pimenta^a and P. Wriggers^b

^aDepartment of Structural and Foundation Engineering
Polytechnic School at the University of São Paulo
P.O. Box 61548, 05424-970, São Paulo, Brazil
campello@usp.br, ppimenta@usp.br

^bInstitute of Mechanics and Computational Mechanics
University of Hannover
Appelstr. 9A, 30167, Hannover, Germany
wriggers@ibnm.uni-hannover.de

In this work we review and extend the geometrically-exact six-parameter shell formulation of [1] and introduce a special triangular shell finite element for the solution of the resultant static boundary value problem. Our approach defines energetically conjugated cross sectional stresses and strains, based on the concept of shell director with a standard Reissner-Mindlin kinematical assumption. Appealing is the fact that both the first Piola-Kirchhoff stress tensor and the deformation gradient appear as primary variables.

Particular attention is drawn in consistently deriving elastic constitutive equations from fully three-dimensional finite strain constitutive models. A genuine plane-stress condition is enforced by vanishing the true (first Piola-Kirchhoff) mid-surface normal stress, not destroying the symmetry of the linearized weak form. This idea is general and can be easily extended to inelastic shells, once a 3-D stress integration scheme within a time step is at hand.

Finite rotations are treated here by the Euler-Rodrigues formula in a pure Lagrangian way. A plane reference configuration is assumed for the shell mid-surface, but initially curved shells can be also considered if regarded as a stress-free deformed state from the plane position. This approach prevents the use of convective non-Cartesian coordinate systems and simplifies the comprehension of tensor quantities, since only components on orthogonal frames are employed. Accurate description of the instantaneously stress-free configuration in finite metal plasticity is thus possible.

The displacement-based triangular shell element of [2] is in addition presented. The element has 6 nodes with a nonconforming linear rotation field and a compatible quadratic interpolation scheme for the displacements. No special (and in some cases expensive) techniques such as ANS, EAS or reduced integration with hourglass control are needed to improve its performance, so that the simplicity of pure displacement-based elements is fully preserved and enjoyed here. Locking is not observed as the accuracy of the element and the robustness of our formulation are assessed by several numerical examples, with a good focus on stability problems. We believe that the combination of reliable triangular shell elements with powerful mesh generators is an excellent tool for the nonlinear analysis of thin-walled structures.

References

- [1] P. M. Pimenta, "On a geometrically-exact finite-strain shell model", *Proceedings of the 3rd Pan-American Congress on Applied Mechanics, III PACAM*, São Paulo, 1993.
- [2] E. M. B. Campello, P. M. Pimenta, and P. Wriggers, "A triangular finite shell element based on a fully nonlinear shell formulation", *Computational Mechanics*, accepted for publication in 2003.